VTT Technical Research Centre of Finland

From Industry X to Industry 6.0

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FROM INDUSTRY X TO INDUSTRY 6.0

ANTIFRAGILE MANUFACTURING FOR PEOPLE, PLANET, AND PROFIT WITH PASSION

FUTURE **WATCH**

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FOREWORD

FROM INDUSTRY X TO **INDUSTRY 6.0**

Europe is in a need to re-invent itself in order to retain the 35 million industrial jobs we still have in a fierce global race on competitiveness and productivity. This needs to happen in concerto with our bold ambitions towards green and digital transition. Digital technologies around us will power Europe´s quantum leap to Industry 6.0 and introducing us into new heights of sustainability, prosperity, and happiness.

Industry 6.0 is defined in this paper as "Ubiquitous, customer-driven, virtualized, antifragile manufacturing". It is characterized on one hand by customer-centric, highly customized lot-size-1 thinking, on the other hand by hyper-connected factories, with dynamic supply chains, where data flows across domains. These also change the role of human as a production worker, as they become part of the interconnected environment and need to handle the digital, optimized production. While we already have strengths that prepare us to lead the next industrial revolution, we also have serious shortcomings. We need to raise Europe´s level of ICT-knowledge across all industries; we need multidisciplinary research, development and innovation, and a strategy for long-term public commitment and significant investments.

This paper represents the thinking among some of the brightest minds in Finland and it is purposed to give food for thought and open new interactions for collaboration across Europe. Humanity is in trouble and therefore we need to join forces not just here in Europe but globally.

CONTENT

ALLIED ICT FINLAND

Allied ICT Finland (AIF) is the largest Nordic research, development and innovation (RDI) alliance in the ICT sector. AIF is a national-level cluster that links Finnish ICT research expertise to business.

AIF PARTNERSHIPS

- 19 universities, other higher education institutes and research organizations
- 12 regional business development companies and institutes
- 1200+ ICT enterprises
- 16 national-level ecosystems

AIF ACTIVITIES

- Bringing together special expertise
- Strategic initiatives and investments
- Participants' shared RDI infrastructures
- National spearhead projects
- EU and international research cooperation
- International business partnerships

AIMING AT IMPACT

The cluster of higher education institutions, research institutes, business development companies and cities within the AIF network aims at combining regional and field-specific areas of expertise, resources, and needs.

BUSINESS COOPERATION AS A RESOURCE FOR FINLAND

The companies in the network implement international product and service solutions for the needs of various sectors.

TEAM AGILITY AND PLATFORM ECONOMY MODELS

AIF utilizes the latest action models, existing research and the capacity of HEIs and research institutes in a coordinated way.

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TIIVISTELMÄ

Tämä raportti esittelee vision ja agendan, jolla Suomi voi ottaa seuraavan teollisen vallankumouksen strategisen veturin ja muutosjohtajan roolin, Teollisuus 6.0 tavoitteiden saavuttamiseksi. riskialttiissa tilanteessa maailmanlaajuisten toimitusverkostojensa ansiosta, maailmanlaajuisten shokkien, kuten pandemian vaikuttaessa. Suomen pitää siis olla rakentamassa täysin uutta teollista vallankumousta, jossa suunnittelun lähtökohtana on epähauras (eng. 'antifragile'), joustava teollisuus, joka kestää tulevaisuuden globaalit shokit. Samoin kuin aikaisemmat teolliset vallankumoukset, tässäkin muutosta ajaa tarve lisätä kasvua ja hyvinvointia. Vakiintuneiden teknologioiden murtamisen ja uusien käyttöönoton kautta saamme valmistusta takaisin Suomeen. Toisaalta, ilmastokriisin ratkaiseminen vaatii sitä, että otamme johtavan roolin ja asetamme strategian, jolla vaikutetaan ympäristön, talouden ja sosiaaliseen kestävään kehitykseen. Suomessa on maailman johtavaa osaamista tieto-ja telekommunikaatioteknologioiden (ICT) tutkimuksessa, ja osa globaaleista ongelmista on ratkaistavissa, kun tutkimus saadaan jalkautettua teollisuuteen. Pitkän tähtäimen kehitysohjelmia kuitenkin vaaditaan uusien älykkäiden ratkaisujen ja dataan perustuvan liiketoiminnan kehittämiseen.

Teollisuus 6.0 määritellään tässä raportissa kaikkialla läsnä olevaksi, asiakaslähtöiseksi, virtuaaliseksi, mukautuvaksi ja epähauraaksi valmistukseksi. Sitä määrittää siis yhtäältä asiakaslähtöinen ja muokattavissa oleva kappalevalmistus ja toisaalta kaikkialle yhteydessä olevat tehtaat, jotka muodostavat verkoston alihankkijoidensa kanssa, luoden arvoverkoston, jossa data liikkuu eri toimijoiden välillä. Myös ihmisen rooli tehtaan työntekijänä muuttuu, kun he tulevat osaksi tehtaan verkostoa. Tämä vaatii uudenlaista osaamista. Suomella on jo monia vahvuuksia johtamaan seuraavaa teollista vallankumousta, meillä on myös vakavia puutteita. Kuroaksemme puutteet umpeen, pitää teollisuuden ICT-osaamista nostaa. Samalla tarvitaan monialaista tutkimus- ja tuotekehitystä, sekä strategia, jossa sitoudutaan pitkäaikaisiin ja huomattaviin investointeihin.

Tässä raportissa ehdotamme Suomelle vahvaa visiota: Seuraava teollinen vallankumous määritellään Suomessa ennakoivilla teollisuutta uudistavilla toimenpiteillä. Visio toteutetaan pitkäaikaisella sitoutumisella ja seuraavien toimenpiteiden toteuttamisella: 1) Suomelle nimitetään Tiede- ja Teollisuusministeri ohjaamaan ehdotettua toimenpideohjelmaa kokonaisvaltaisesti. 2) Nykyisiä alueellisia älykkään erikoistumisen strategioita tarkennetaan niin, että jatkossa voidaan nykyistä paremmin hyödyntää Euroopan Alueellisen Rakennerahaston (EAKR) rahoitusta sekä edistää alueiden välistä yhteistyötä. 3) Perustetaan virtuaalinen Industry 6.0 yliopisto, johon tulee noin kymmenen uutta teollisuuden ICT-alojen professuuria sekä muita tutkimuspositioita, jotta tarvittava tutkimusosaamisen vaje saadaan kurottua kiinni. 4) Avataan testitehdas, joka on avoin suomalaisille toimijoille, ja joka edistää suomalaisten teknologisten alustojen hyödyntämistä uusien ratkaisujen kehittämisessä. Verkostomaisesti toimivan testitehtaan puitteissa kehitetään sitä tukeva kokeilumalli, joka yhdistää älykkään erikoistumisen, yhteistyössä tapahtuvan valmistuksen ja jakaa tutkimus-, tuotekehitys- ja innovaatioympäristöt teollisuuden ja tutkimuksen käyttöön. 5) Perustetaan suomalaiselle teollisuudelle muutoskiihdyttämö, jonka sisältö linjataan tukemaan Suomen European Digital Innovation Hub (EDIH) –valintoja.

EXECUTIVE SUMMARY

This white paper addresses the potential pathways the Finnish industry must take in order to be the strategic leader and driver towards defining "Industry 6.0". The recent global economic situation has revealed that Finnish industry is affected by risks caused by the pandemic, global supply chains and dependency of suppliers all around the world. Therefore, we need to build up a completely new industrial revolution, in which antifragility is the design principle to increase our resilience to future stressors and global shocks. Like earlier industrial revolution, advances in technology have paved the way to creating growth and well-being. Disruptive technologies, such as 3D printing and AI are an opportunity in localization of manufacturing back to Finland. The global climate crisis requires us to be at the forefront of a strategy that creates impact on the environment, economy, and society. Here, the Finnish ICT expertise can solve problems, as long as the support of taking research results out into the industry is supported. The essential component in creating intelligent solutions and new business is data. Long-term development programs are needed for understanding what the use of data unlike ever before will imply for businesses, customers, ethics and regulations.

Industry 6.0 is defined in this paper as "Ubiquitous, customer-driven, virtualized, antifragile manufacturing". It is characterized on one hand by customer-centric, highly customized lot-size-1 thinking, on the other hand by hyper-connected factories, with dynamic supply chains, were data flows across domains. These also change the role of human as a production worker, as they become part of the interconnected environment and need to handle the digital, optimized production. While we already have strengths that prepare us to lead the next industrial revolution, we also have serious shortcomings. We need to raise the level of ICT-knowledge across industry; we need multidisciplinary research, development and innovation, and a strategy for long-term public commitment and significant in-vestments.

We propose that Finland assumes a strong vision: Industry 6.0 is defined in Finland by proactive game-changing actions. This vision is realized in a long-term commitment to implementing an agenda of the following. 1) Finland nominates a Science and Technology minister to steer the activities. Their task would be to steer the implementation of the agenda holistically. 2) Current smart-specialization strategies need to be specified more carefully in order to utilize funding from the European Regional Development Fund (ERDF) more efficiently and in a coordinated matter. 3) Creation of the Virtual Industry 6.0 University, and approximately 10 new Industrial ICT professors and additional postdocs are needed to fill the gaps. 4) Creation of a test factory opening access of the environments broadly and serving as a testbed for Finnish winning platforms. With the network-based test factory, we can create a new pilot model in Finland combining the models of smart specialization, smart co-creation and shared RDI environments to ensure our industry competitiveness. 5) Establishing a digital transformation accelerator for Finnish industry, aligning the accelerator to European Digital Innovation Hubs selections.

1. INTRODUCTION

This white paper is about “Industry X”, the Finnish industry currently at a crossroads. Our world is changing so dramatically that industry must renew itself. The question, then, is which road to take?

Our answer is that the Finnish industry should boldly take the leading role towards what we call “Industry 6.0”. We can be the initiators and drivers specifying what Industry 6.0 is and will be, and we can be the game changers implementing it first. Through partnering and close collaboration at the European level and by utilizing Europe's common leverage, we can strengthen the position of Finland and Europe. Moreover, it can be done not just for Finland and Europe, but for the whole planet, profitably and with passion.

FINNISH INDUSTRY FROM THE CROSSROADS TO THE PATH OF THE INDUSTRIAL REVOLUTION INDUSTRY 6.0

1.1 From Crisis to Transition

Throughout its history, industry has proven its ability to lead transformation. And it shall do the same in the times of transition towards climate neutrality and digital leadership in an ever-changing and ever-unpredictable world. We are already in the midst of a significant transformation regarding the way we produce products and deliver services thanks to the digitization of manufacturing and the new connected supply chains and co-creation systems.

We are also in the midst of an unprecedented global shock. Every economic shock leaves a legacy. Finnish industry is currently under pressure from four simultaneous shocks: Brexit, the tensions between Russia and the European Union, the US-China trade war, and the coronavirus disease (COVID-19) pandemic. These shocks will be no different; they will have a heavy legacy. For instance, the coronavirus disease causes lockdowns altering our habits of both consumption and production. These lockdowns will ease, step by step. However, they might act as a brake on demand for a long time.

The global crisis also affects the supply side as manufacturers are being forced to rethink where to produce their goods. In this way, the COVID-19 pandemic accelerates the need to answer the risks of relying on one source for components caused by the US-China trade war. COVID-19 also made extremely visible how reliant Finland actually is; we are truly reliant on Chinese components and highly reliant on US software. In addition, Brexit affects supply-demand chains especially in the EU. Altogether, the quadruple convergence of Brexit, Russia in the cold, the US-China trade war and COVID-19 have opened our eyes to see how vulnerable our current industry and its value chains are.

In an ever more connected world, impacted by climate change and the biodiversity crisis, there is little to suggest that we will be less exposed to global risk in the

future. If we want to prepare for future shocks, we must put more focus on the aspects of sustainability, robustness, safety and resilience. This means that we need to build up a completely new industrial revolution, Industry 6.0, with antifragility as a design principle. Antifragility is a property of systems in which they increase in capability to thrive as a result of stressors, shocks, volatility, noise, mistakes, faults, attacks, or failures.

ROBUSTNESS IS NOT SUFFICIENT - WE NEED ANTIFRAGILE INDUSTRY

Furthermore, changing consumer behavior is already driving rapid changes to the manufacturing industry today. The complexity of manufacturing is increasing with the rapidly growing variety and intricacy of more intelligent products, speed, with more pressure on quality and with sustainability demanded also by B2B customers. Products are expected to be delivered as "perfect orders" and these expectations take place in a global marketplace.

Finland is seriously affected with all this development. Whether the effects will be positive or negative depends on our activities in the new situation. As a high-cost small country, we will need a clear agenda for our future survival. To survive financially (and to provide a smart, sustainable, and safe society in general), Finland needs to solve the question: *How to reindustrialize Finland and the local production, but profitably, with environmentally friendly manufacturing and re- and de-manufacturing, leading to less waste and reduced emissions?*

We need to help the industry to survive the current shocks and to make them much more resilient against future shocks. This alone is far from being enough as we need to increase the competitiveness of the Finnish industry significantly compared with the competitors. We need to, in other words, transition from the uncertainty of the crossroads of Industry X to the new paradigm we define as Industry 6.0. The technological revolution arises from the transition from Industry X to Industry 6.0

THE TECHNOLOGICAL REVOLUTION ARISES FROM THE TRANSITION FROM INDUSTRY X TO INDUSTRY 6.0

New ideas and innovative technologies create growth and well-being for society [1,2]. For businesses, technological change alters the operating environment. As we know from history, transformations have been associated with earlier transitions

[1] Source: Kaivo-oja, J., Lauraéus; T. & Knudsen, M. S. (2020) Picking the ICT Technology Winners - Longitudinal Analysis of 21st Century Technologies based on the Gartner Hype Cycle 2008-2017: Trends, Tendencies, and Weak Signals. International Journal of Web Engineering and Technology, 2020 Vol.15 No.3, 216–264.
[2] Source: Iansiti, M. & Lakhani, K.R. (2020) Competing in the Age of AI: Strategy and Leadership When Algorithms and Networks Run the World. Boston: Harvard Business Review Press.

and revolutions [2,3,4]. New technologies in transition and digitalization can change the operations of businesses, and they have a particular impact on the global economy [1,2,5].

Technology is evolving rapidly and at the same time changing our operations and new applications are rapidly being introduced. In the face of a technological revolution, company leaders need information on what changes and opportunities are promised, but also foresight leadership tools and clear visions of future [6]. Emerging innovation theory focuses on key issues such as market characteristics, new markets, and cutting-edge innovation [7,8]. New technology can create new markets, radically change or disrupt existing markets [5,8]. Technology affects the way we work, the structures of society and organizations. Utilization of technology requires more and more changes in business, thinking and operating methods [8]. On the other hand, it is also the case that when businesses, mindsets and operating methods change, new orchestration needs arise because the changes are not already integrated for companies and other actors [9].

SUPERIOR PRODUCTIVITY NEEDED

Thanks to disruptive technologies such as 3D/4D printing and artificial intelligence (AI), Finland can make the most of localization as an opportunity to bring more manufacturing back to Finland. The small size of the local market and the future needs for increased personalization pose the fundamental question and opportunity for Finland: How to make the lot-size-1 economically feasible.

Over the past 35 years, industrial manufacturing has moved towards increasingly complex Global Value Chains (GVCs) with increasing shares of product manufacturing happening in far-away, low-cost countries. In recent years, even before the current crisis situations, there have been signs that this development is changing. Value chains are experiencing a regional rebalancing, which makes the topography of production more varied and distributed.

State-of-the-art manufacturing technologies aids this shift. With increased use of automation, robotisation, AI, and digital operating models (Figure 1), the importance of high-cost environments decreases, and the importance of skilled labour capable of constructing, operating and (re)programming the advanced

[3] Source: Floridi, L. (2014) The 4th Revolution. How the Infophere is Reshaping Human Reality? Oxford University Press. Oxford.
[4] Source: Ross, A. (2016) The Industries of the Future. Simon and Schuster. New York, USA.
[5] Source: Bower, J. L. & Christensen, C. M. (1995) "Disruptive technologies: Catching the wave. Harvard Business Review video," https://hbr.org/1995/01/disruptive-technologies-catching-the-wave, 1995.
[6] Source: Kaivo-oja, J. & Lauraeus, T. (2019) Analysis of 2017 Gartner's Three Megatrends to Thrive the Disruptive Business, Technology Trends 2008–2016, Dynamic Capabilities of VUCA and Foresight Leadership Tools. Advances in Technology Innovation, Vol. 4, No. 2, 2019, 105–115.
[7] Source: Christensen, C. M. (1997) The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail. Boston: Harvard Business School Press.
[8] Source: Kaivo-oja, J. & Lauraeus, T. (2018) The VUCA approach as a solution concept to corporate foresight challenges and global technological disruption. Foresight, The Journal of Future Studies, Strategic Thinking and Policy, 20(1), 27–49. Roth, S., Melkonyan, A., Kaivo-oja J., Manke, B. & Dana, L.-P. (2018) Interfunctional business models. Map to an uncharted quadrant of the Blue Ocean. International Journal of Entrepreneurial Venturing, Vol. 10, No. 5, 581–595.
[9] Source: Roth, S., Leydesdorff, L., Kaivo-oja, J. & Sales, A. (2019) Open Coopetition: When Multiple Players and Rivals Team Up. Journal of Business Strategy, Vol. 41 No. 6, 31-38.

machinery increases. At the same time demands shift from mass-markets to niche markets, mass-customization and mass-personalization. Manufactures serving end consumers (B2C) as well as suppliers for other businesses (B2B) face similar trends; they must increasingly deliver flexibility, complexity and high-quality small batch-production. Soon, in Industry 6.0, this is further reduced to lot-size-1. To achieve this target much superior productivity is needed.

The critical precondition of superior productivity is the broad use of digital operating models instead of traditional operating models (see Figure 1). Digitalizing the best understanding of operational excellence through the broad-based application of AI and machine learning, advanced robotics and the instantiation of as much know-how as possible into software. This smart approach is highly relevant for the Allied ICT Finland and other innovation ecosystem partners. The largest research to business ICT network in the Nordics has much to say and contribute to this special issue.

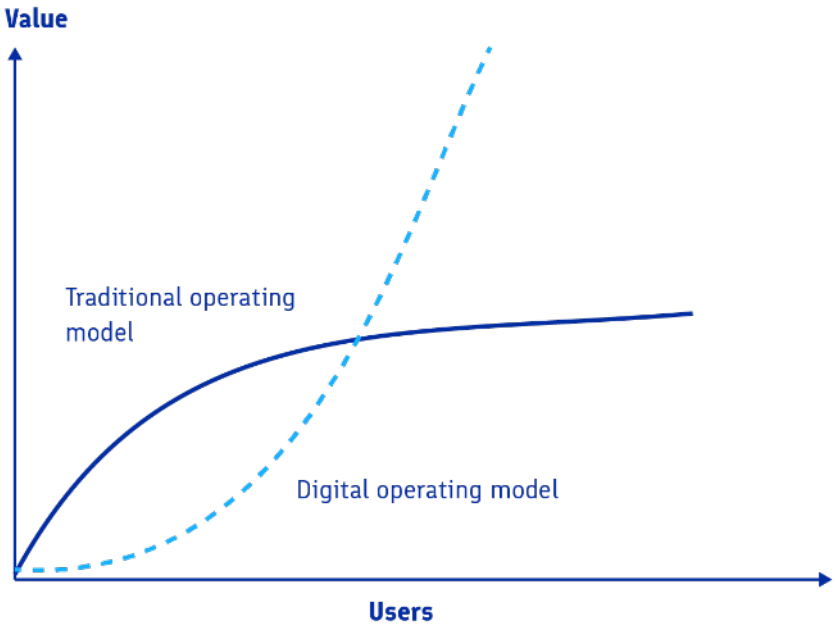


Figure 1. ***The collision between traditional and digital operating models*** [10]

Becoming a more digital company is an obvious challenge of the era of digital operating model(s). Aiming to be more customer-oriented, more convenient, more price-efficient, more personalized and more sustainable and having more marketing power requires keen attention to digital operating models. In addition, three pillars of foresight are needed: smart foresight methods, network and stakeholder analysis tools, and AI-based decision support systems.

[10] Source: Iansiti, M. & Lakhani, K.R. (2020) Competing in the Age of AI: Strategy and Leadership When Algorithms and Networks Run the World. Boston: Harvard Business Review Press.

CUSTOMER-DRIVEN INDUSTRY – MIXTURE OF GLOBALITY WITH STRONG LOCALITY

The concept of sustainability is traditionally composed of three pillars: economic, environmental, and social - also known informally as profits, planet, and people. Survival is thus not only about economic survival, where focus is often mainly in the short term. Global challenges, such as the climate and biodiversity crises, frame survival challenges framing the survival decisions for the long term. Recognising these long-term challenges and considering the current uncertain shock situations the patterns of fragility of many current business strategies and business models are clear. They are unfit for uncertainty or fast radical changes in the business environment. We propose that Finland and the Finnish industry should create Green Ocean-strategies where impacts on the environment, economy, individuals, and society are balanced. This means strategies aligned with Sustainable Development Goals (SDGs), with long-term thinking, and built on antifragility-by-design.

GREEN OCEAN STRATEGIES FOR FINLAND AND FINNISH INDUSTRY

To achieve this, Finland needs to be at the technological forefront of the world. The most important developments will take place in digitalization and auto-mation, e.g. 5G/6G-connectivity, AI (that will be especially exploited to be used in the intelligent network edge), autonomous systems, and the capability to integrate subparts into total systems. Finland is well known to be a global research leader in many of these areas, and academic-industry collaboration can ensure knowledge creation is embedded in the Finnish industry to the full extent. In 2020, Minister of Economic Affairs Mika Lintilä initiated the Artificial Intelligence 4.0 programme for Finland to accelerate the introduction of artificial intelligence and to promote the fourth industrial revolution. The programme recently proposed a target state which should be pursued in the development and utilization of digitalization for the fourth industrial revolution in collaboration with companies, public organizations, and research, academia and training institutes. Another emerging disruptive technology, which is heavily invested by the large ICT players globally, is quantum computing. In Finland, VTT Technical Research Centre of Finland and IQM have entered into a government-subsidized co-innovation partnership to build a Finnish quantum computer. As a horizontal technology, quantum computing can impact multiple existing technologies and use cases, and thus needs to be carefully followed and utilized as part of future technology roadmaps.

ICT PLAYS THE KEY ROLE IN THE PATH TOWARDSINDUSTRY 6.0

However, mastering the key technologies alone is not sufficient. The oil for any intelligence lies in data. Data needs to be gained, understood and analyzed before, e.g., new business models, processes, and value chains for the business-front can be developed. Equally important is the understanding of human issues (such as UX, ethics, etc.). Broad scale long-term development programs are needed to combine the interrelated parts of the triplet: business, human, and technology. We must rely on our strengths and systematically strengthen our current weaknesses. This is done by interlinking Finnish research and networking with key players in the world. Specific emphasis in the development programs should be placed on the fast dissemination of research results to the industry, including SMEs. Born global SMEs can be developed in the key areas with the support of government, research and large industries serving as reference customers and helping in globalization.

HOLISTIC LONG-TERM DEVELOPMENT AGENDAS

The first step towards Industry 6.0 comes with the realization of Industry 4.0. It is therefore relevant to consider the building blocks of the Fourth Industrial Revolution. It is important to understand the direction of future development, i.e. where digitalization and the development of new technologies are leading us. This is shown in Figure 2, which elaborates on the current Industry 4.0 vision [11].

[11] Source: Ghobakhloo, M. (2018) The future of manufacturing industry: a strategic roadmap toward Industry 4.0. Journal of Manufacturing Technology Management, Vol. 29, No. 6, pp. 910-936.

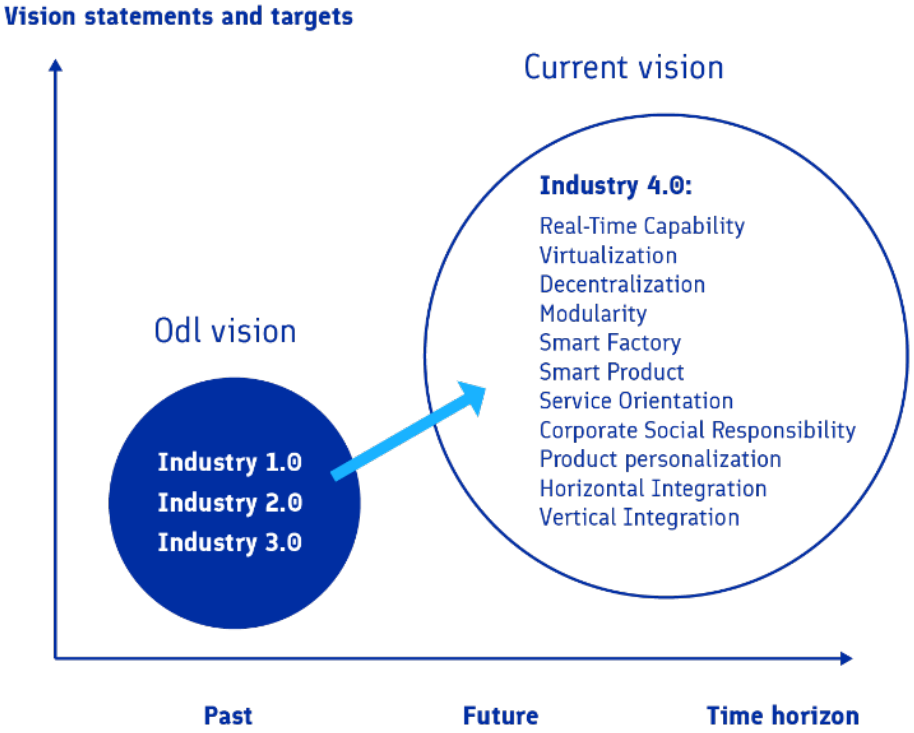


Figure 2. ***Old and current vision of industrial development***

When presenting visions and strategies for the future, surprisingly often, the starting points are point-like ideas and linear instead of taking into proper account the complexity of different systems. Therefore, when discussing future industrial solutions, it would be advantageous to see industry visions in a multidimensional way. In the future of industrial development, one way to reach better visions is to move from *the Pointland* to *the Spaceland*. In Figure 3, we have visualized this challenge for the next phases of industrial r/evolution.

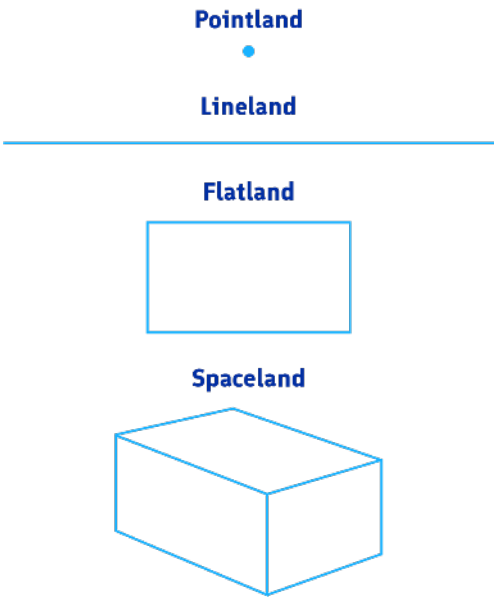


Figure 3. ***From Pointland to Spaceland – A key idea to more impactful visions*** [12]

[12] Source: Ariel, G. (2017) Augmenting Alice. The Future of Identity, Experience and Reality. BIS Publishers. Amsterdam.

The key message of Figure 3 is that we should think about the future as a multidimensional space. When designing our vision, and our paths towards that vision, we are not looking towards a singular end-path. Rather, we are opening up space to fulfill many simultaneous aspirations. Furthermore, as Galit Ariel [12] points out, we need more Post- and Hyper-realism, because future systems are not only reliant on physio-physical dimensions, but also include augmented and virtual dimensions of thinking. When we think of the future Finnish industry the mental map we need is not only two-dimensional (altitude, latitude), but also includes the sky and clouds above.

The implementation of visionary multidimensional thinking requires the use of the packetization cube framework as a starting point of forward-looking business modelling. There are eight business model alternatives in the platform economy (see Figure 4). All companies must think or rethink their position in the cube. Companies must align their strategic architecture, governance, and strategy from a three-dimensional perspective. Fast movement inside the cube may be needed in value-producing networks and markets. Still, it is impossible to be absolutely sure if they have positioned their company in the right strategic way or in the right place.

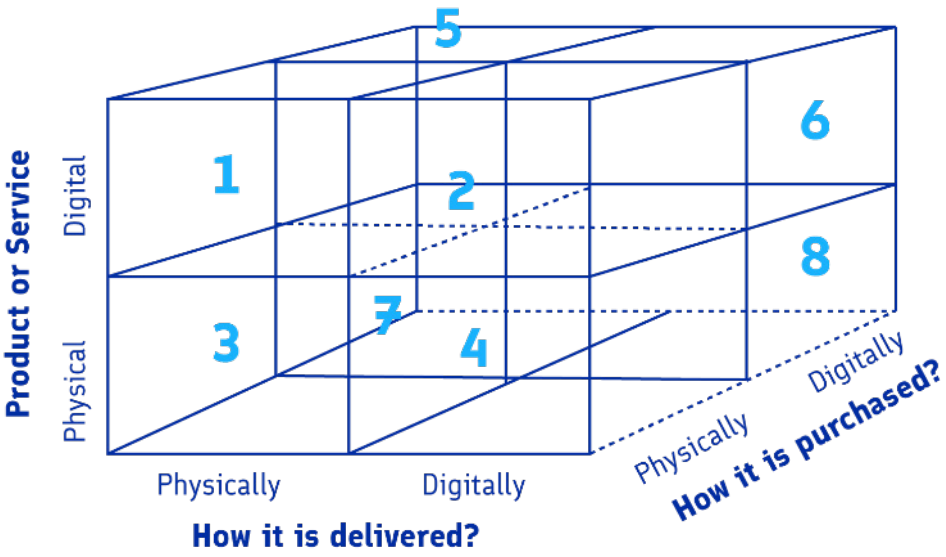


Figure 4. ***The packetization cube framework as a starting point of the platform economy*** [13]

[13] Source: Tiwana, A. (2014) The Rise of Platform Ecosystems. Morgan Kaufmann. Boston.

1.2 Defining Industry 6.0

The European Commission recently launched the Industry 5.0 approach 14. According to the approach, Industry 5.0 complements the existing Industry 4.0 paradigm by highlighting research and innovation as drivers for a transition to (1) a sustainable, (2) human-centric and (3) resilient European industry. Focus is moved from shareholder to stakeholder value with material and immaterial benefits for all concerned. The approach aims to capture the value of new technologies, provide prosperity beyond jobs and growth while respecting planetary boundaries, and put the wellbeing of industry workers at the center of the production process. This means an increasing role for human factors in planning and engineering in the future. Technical specifications, business specifications, service specifications must be integrated to inclusive social systems in a better way than today. Greater service orientation and Service Dominant Logic (SDL) of industries will be key elements on Industry 5.0 and Industry 6.0 approaches. The SDL approach will be linked to 3R sustainability strategy: Reduce, Reuse and Recycle.

We propose that Finland announces that Industry 6.0 will be defined in Finland. We take the lead and combine the expertise of other countries to not only define Industry 6.0, but to have it implemented in Finland first. Our starting hypothesis is that the following issues characterize the path from the current Industry 4.0 to Industry 6.0:

INDUSTRY 4.0:
"CONNECT - IOT TO CREATE CYBER-PHYSICAL SYSTEMS FOR ANALYTICS-BASED ACTIONABLE INSIGHTS"

- Supply push, production-centered thinking
- Smart technology at the forefront of manufacturing
- Interoperability for machines, devices, and people to connect and communicate with each other via internet and other networks at factory floor
- Digital twins 1.0
- Heterogeneous data sources
- Information transparency, decentralized decisions
- Technical assistance to support people by aggregating and visualizing information
- Functional materials provide new opportunities

[14] Source: European Commission (2021) Industry 5.0. Publications Office of the European Union. Luxembourg.

INDUSTRY 5.0: "CO-EXIST - HUMAN-MACHINE CO-CREATIVE RESILIENT AND SUSTAINABLE CYBER-PHYSICAL SYSTEMS FOR MASS-CUSTOMIZATION"

- Mix of supply push and demand pull
- Human in focus
- Increased collaboration between humans and smart systems, cobotics
- Mass-customization enabled
- Circular economy in focus
- Sensor networks and edge computing for environment analysis
- Re/de-manufacturing
- zero waste, zero emission
- Digital twins 2.0 providing understanding not only about the factory-processes but the whole environment
- Complexity increase[2]
- Product complexity is increasing as a result of the adoption of advanced technologies in products and processes and ever-increasing customer expectations
- The complexity of value networks is steadily increasing

INDUSTRY 6.0: "UBIQUITOUS - CUSTOMER DRIVEN VIRTUALIZED ANTIFRAGILE MANUFACTURING"

- Demand pull, customers in the centre of thinking.
- Hyperconnected factories in complex, dynamic supply chains and value networks, where data flows across different administration domains. Requires a common data model.
- Human digital twin connects manufacturing
- For example, take a picture of a rough sketch and click "make it"
- Role of human dramatically changes in manufacturing
- Sort of analogy from ICT, production is like cloud capacity, "factories" sell production capacity similarly to, e.g., Amazon selling computing capacity
- AI optimizes the production to obtain sustainability and antifragility
- lot-size-1 made economically feasible
  Antifragility obtained via the design of systems relying on Non-Functional Requirements (NFR) -thinking

PATH TO INDUSTRY 6.0 IS PAVED WITH ICT-SOLUTIONS

This paper addresses especially the role of ICT in this survival game. Our claim is that ICT plays a major role in the game. An illustration of Key Enabling Technologies in the transition from Industry 4.0 to Industry 6.0 is shown in Figure 5.

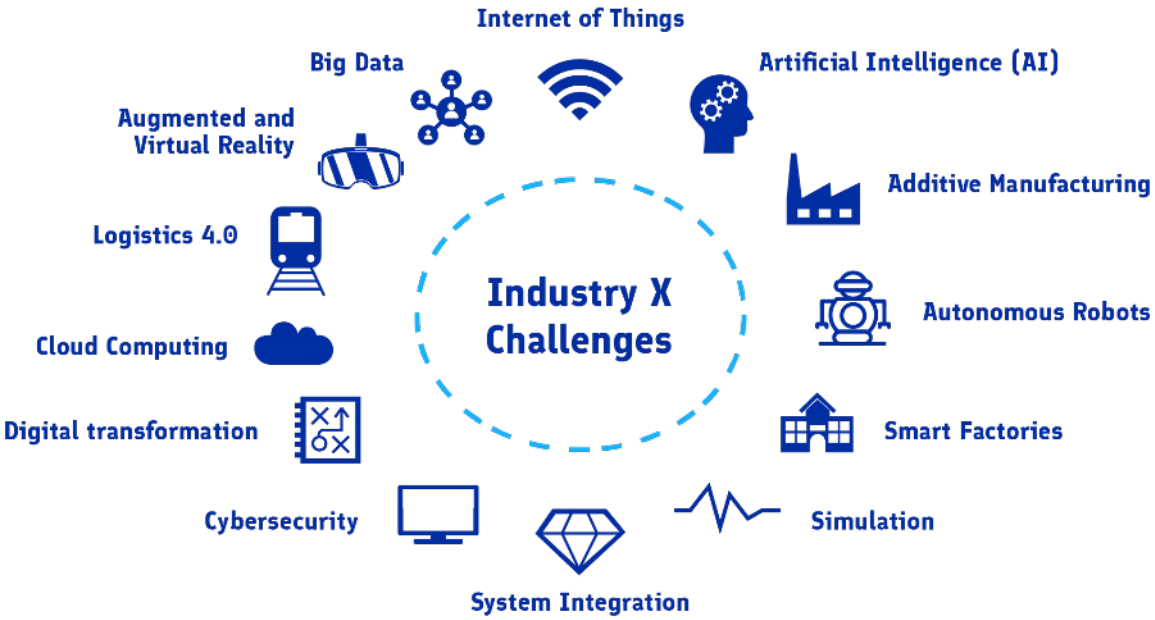


Figure 5. ***Key Enabling Technologies in the transition from Industry 4.0 to Industry 6.0***

Finland has many specific strengths within these technological fields, but serious shortages as well. Now is the time for Finland to react and to act strategically aiming high. As Milton Friedman said, *"Only a crisis – actual or perceived – produces real change. When that crisis occurs, the actions that are taken depend on the ideas that are lying around"*. Soon, hopefully, the world will start to bounce back from current shocks, and the world will reform itself along with the ideas lying around. Finland now has a unique opportunity to shape these ideas and to shape the future global development. This requires long-term public commitment and significant investments. Let us solve the following questions, systematically.

1. How to **utilize disruptive technologies** to their full potential

   a. Especially 5G+**6G** enabled and intelligent edge
      i. maximize network capability
      ii. computing architecture to optimize / minimize telecommunication
      iii. ability to exploit best available carrier; heterogeneous networks

   b. **AI**
      i. **Data for AI**, (domain specific), sensors, IoT, big data, data security, data management, semantics, open data
      ii. Machine learning, teaching capabilities

iii. **AI-powered edge**, distributed computing architecture
iv. **Role of AI**, how much power it can be given in the path from Industry 4.0 to Industry 6.0? Ethics? Can AI be actionable?

c. Blockchain

d. Functional materials, their design, adding intelligence to materials, printable/additive processes

e. Autonomous systems

2. How to enable **digital transformation** for companies of all sizes

a. Affects manufacturing industry at all levels from
i. customer interaction
ii. to supply networks
iii. to machines and
iv. to workers at shop floor

b. provides means to address challenges such as
i. mass customization
ii. increased personalization and eventually **lot-size-one production**
iii. re- and de-manufacturing
iv. zero-defect manufacturing
v. circular economy
vi. integration of products and services
vii. accelerated globalization
viii. fully integrated, automated and platform-based supply nd value networks

c. enables continuous improvement in
i. flexibility
ii. productivity
iii. quality
iv. accuracy
v. security
vi. sustainability

3. The old systems and technology will not disappear overnight. How to handle this **legacy** combined with the changing digital landscape? How to integrate Industry 5.0 and 6.0 solutions to existing systems, infrastructure and production lines?

a. How to create roadmaps for the change?
b. How to implement and govern steps for Industry 5.0 and 6.0?
c. How to succeed in data and service integration when moving to Industry 6.0 via 5.0?

   d. How to overcome the obstacles in existing infrastructure, skills, attitudes and management?

4. How to **organize change** and development in the industry?

5. How to develop **agile** manufacturing systems and whole elastic value chains

   a. Agility in all levels, collaborative R&D&I, operations, design, …

6. How to **design antifragile systems** (the next generation of resilience)

7. How to ensure positive impacts on **sustainable development goals** on different levels

8. How to develop **education** for the survival game

9. How to utilize **new business logics and models**

   a. Mastering product complexity with on-demand, personalized products will require new collaboration structures and networks.
   b. New paradigms – sharing economy and outcome economy – require new logic

2. ANALYSIS OF THE FINNISH SITUATION

This chapter illustrates the current state of manufacturing digitalization in Finland. Neither the Finnish industrial landscape nor the academic research community is homogenous across the country. Therefore, there is a need for place-based differentiation to play off various regional strengths as well as to identify potential challenges in particular regions. This mindset is embodied by the concept of Regional Smart Specialization Strategies (S3), which has become a key instrument in the European strategic vision for work and prosperity. The analytical tool has practical usability too, as significant amounts of EU-funding is now tied to S3-implementation.

INDUSTRY IS IN THE SMART-SPECIALIZATION STRATEGIES OF MOST AREAS WITHOUT REAL SPECIALIZATION

A recent report developed a new Smart Specialization Index (SSI) based upon extensive analysis of Finnish regional smart specialization[15]. The SSI helps in 1) creating critical mass for innovation activities, 2) lessening overlap from functions, 3) mitigating risks in innovation activities and 4) facilitating new types of entrepreneurship. In this chapter, selected active innovation ecosystems are presented from different regions. In addition, current gaps in know-how can be identified against the current ecosystem descriptions, leading to suggested actions in chapter three.

DURING THE NEXT FEW YEARS, THE EUROPEAN UNION WILL INVES HUNDREDS OF BILLIONS OF EUROS IN THE DOUBLE CHALLENGE OF GREEN TRANSITION AND REINDUSTRIALIZATION OF EUROPE. BEING A LEADER WITHIN THESE DEVELOPMENTS SHOULD BE AMONG THE HIGHEST PRIORITIES OF FINLAND IN THE POST-COVID-19 ERA. INDUSTRY X UNDERPINS THIS AMBITION.

[15] Source: Karppinen, A., Aho, S., Haukioja, T., Kaivo-oja, J. & Vähäsantanen, S. (2019) Alueiden älykäs erikoistuminen Suomessa: aluekehittämisen indikaattorianalyysi. Turun yliopisto, Tulevaisuuden tutkimuskeskus. TUTU eJULKAISUJA.

2.1 Focus Areas in R&D

Here, we look at regional focus areas and research competences through the Industry X lens. To capture sufficient value and benefits from innovation and smart specialization there is a need for the establishment of innovation ecosystems between R&D and SME -level industry players in selected competence areas. There is also a need for strong interdisciplinarity and for shared visions between tech- and data-professionals on the one hand and manufacturing industry practitioners on the other. Bridging this gap within functioning ecosystems is a key to unlocking regional R&D potentials on the path towards Industry X.

THERE IS A LACK OF ICT-PROFESSIONALS IN THE INDUSTRY, ESPECIALLY SOFTWARE

Research organizations around Finland have often aligned themselves with regional smart specializations. For example, research organizations in Tampere region have a strong focus on manufacturing industry-related research, whereas the University of Oulu and VTT Oulu have aligned their specialization with next generation telecommunications research. Other examples of strong specializations are cybersecurity at University of Jyväskylä, smart digitalization in Turku, Kuopio and Lappeenranta, and a strong energy cluster focus in research (and business alike) in the Vaasa-area. The Capital Region is a somewhat unique, less specialized, case as the region attracts business and research across a wider range of fields.

MANY RDI ENVIRONMENTS EXIST – BUT NOT WIDELY ACCESSIBLE

At the same time as ecosystems must adapt to their regional capabilities, pooling competences into national ecosystems is another important step. An example of joined collaboration between Finnish industry and research organizations to pool their know-how and invest in the future is Finnish Institute of Technology, FITech, started in 2017. With this new type of network university, research organisations are able to specialise further in particular research strongholds, while at the same time offering their world-class niche to a wider audience beyond their traditional geographical scope. Students in Finland – and, with time, increasingly outside Finland – get broader access to world-class Finnish technology-centred education. By connecting the existing RDI environments into network-structured organisations, access to these environments are thus radically increased. New platforms or platforms using the now existing cooperation structure could be further developed (and expanded) and act as a joint education and innovation platforms. These can be lifelong-learning places where Industry X and Industry 6.0-professionals meet to educate each other and students (both degree students and adult learners). Simultaneously, such platforms would ensure increased contacts between all key stakeholders (universities, businesses, and society), promote joint research and innovation projects, and increase the attractiveness of Finnish universities in the eyes of future students, foreign professionals, and companies.

There are already signs of shortages of skilled professionals in certain relevant fields. Upskilling Finnish students and professionals, as well as attracting international talent are therefore key elements of a successful Industry 6.0-strategy. If the Finnish RDI environments can be some of the best and some of the most accessible in the world, it would go a long way in mitigating this challenge.

2.2 Finnish Business Landscape

Finland is one of the world's advanced and richest countries that has benefitted from world-class education, globalization, openness, and the market economy. Due to the small domestic market, exports are vital for Finnish businesses. Structural changes in the 1990s, Nokia downsizing and the finance crisis had large impacts on the economy. In the 1990s, the Eastern trade collapsed, and domestic demand declined. Yet, the exports grew due to the currency devaluation. In the mid-1990s, the value added in the electronics and electrical products sector exceeded traditionally strong wood and paper and machinery and equipment sectors. In 2000, almost 90 % of Finnish exports were industrial goods, but the share of service exports has now grown to almost 30 %. The last decade was mostly a time of slow growth due to the collapse of Nokia's production, the finance crisis and the decline in cost competitiveness. In recent years, both the cost competitiveness and the exports have increased again. The current challenges in Finland include a deficient public sector, aging population, and increasing international competition.

Services' share of Finland's GDP has grown to over two thirds as industrial production has decreased. According to the Confederation of Finnish Industries [16], roughly 75 % of the services are provided by the private sector, whereas the share of public services is approximately 25 %. The most important service sectors include retail and trade, traffic, information and communication, and real estate. The share of services in GDP has grown due to outsourcing of, for example, information processing services and expert services. Over 1.9 million employees are working in services, out of which 1.2 million in private sector services. The government employs 130 000 and the local governments 470 000 people.

Exports are vital for Finland and they represent the strongest areas of Finnish business. Total service exports were 27 billion euros in 2018. The biggest exports were IT services. Overall high tech, engineering and technical services are important. However, the majority of exports are still physical products. In 2018, total goods exports were 63.8 billion euros with 7 % annual growth. The share of the largest exports are as follows [17]:

[16] Source: Perustietoja Suomen taloudesta. Confederation of Finnish Industries. https://ek.fi/tutkittua-tietoa/tietoa-suomen-taloudesta/
[17] Source: Ulkomaankauppa. Confederation of Finnish Industries. https://ek.fi/tutkittua-tietoa/tietoa-suomen-taloudesta/ulkomaankauppa/

- Pulp, paper and paper products 16.1 % and wood and wood products 4.4 %
- Chemical industry products 19.3 %
- Metal and metal products 15.5 %
- Machines and equipment 12.8 %
- Electric and electronics products 11.7 %
- Vehicles 8.4 %

A STRONG AND RESILIENT INDUSTRY BUILT ON HIGH-VALUE ADDED PRODUCTION IS THE MAIN DRIVER OF FINNISH ECONOMIC SUCCESS IN THE 2020s AS THE ADDED VALUE OF FINNISH MANUFACTURING GROWS SIGNIFICANTLY BEYOND THE CURRENT ANNUAL FIGURE OF 30 BILLION EUROS.

Finland is in a global context a high-cost environment. Competition based solely on price is therefore rarely an option for Finland as an export economy. Instead, in addition to cost control, the development of knowledge and competences are very important for Finnish businesses. The continuous availability of skilled labour through education and life-long learning plays a key role, and the primary market potential comes through high value products and services.

Recent shocks, and especially the COVID-19 crisis, has caused at least a short-term recession. It could also have long-lasting impacts on the global economy and supply networks, as businesses and countries have become aware of the vulnerability of global supply networks.

Finnish businesses are strongly dependent on international suppliers. Companies source currently a large share of key components and materials, such as electronic components, parts of motor vehicles and medical products and their ingredients from abroad. Over 80% of these intermediate goods/products are from international sources. The most import-dependent industry sectors in Finland include oil product industry, chemical industry, and electronics industry, as well as vehicle manufacturing and pharmaceutical industry. Dependency on imports is much lower in the service sector and food, agriculture, and energy industries. [18]

Finland is also dependent on international trade as a supplier itself of immediate products. As much as three-fourths of Finnish exports are intermediates, that is

[18] Source: Ali-Yrkkö J. & Kuusi T. (2020) Korona-sokki talouteen – Missä määrin Suomi on riippuvainen ulkomaisista arvoketjuista?. ETLA Muistio - ETLA Brief 87. https://pub.etla.fi/ETLA-Muistio-Brief-87.pdf

goods and services that are used by others to produce final products[19]. In fact, in recent years the share of intermediates of total exports has been higher for Finland than for any country in EU-28.

THE BRAND OF INDUSTRY FOR MILLENNIALS IS OLD-FASHIONED. REBRANDING IS NEEDED – (1) TO HAVE ENOUGH FUTURE PROFESSIONALS, AND (2) TO HAVE A FLOURISHING STARTUP SCENE.

In addition to current strengths of Finnish businesses, future growth opportunities must be considered. Promising future business opportunities based on Finland's strengths can be found in information and communication services, carbon neutral transportation, circular economy, autonomous factories, food production, biomaterials, health and wellbeing, human capital, diverse construction, and housing, and finally in digitalization of everything. EU-policies for the upcoming decade create opportunities for Finnish companies and are summarized in Figure 6. Some of these are also discussed in the report Opportunities for Finland [20].

[19] Source: Ali-Yrkkö, J., Heikkilä, J., Lööf, H., Martinsuo, M., Mohammadi, A., Olhager, J., Pajarinen, M., Rouvinen, P. & Tuhkuri, J. (2017) International Sourcing in Finland and Sweden. ETLA B 275.
[20] Source: Mahdollisuudet Suomelle. Valtioneuvoston julkaisuja 2019:1. Valtioneuvosto. http://urn.fi/URN:ISBN:978-952-287-688-1

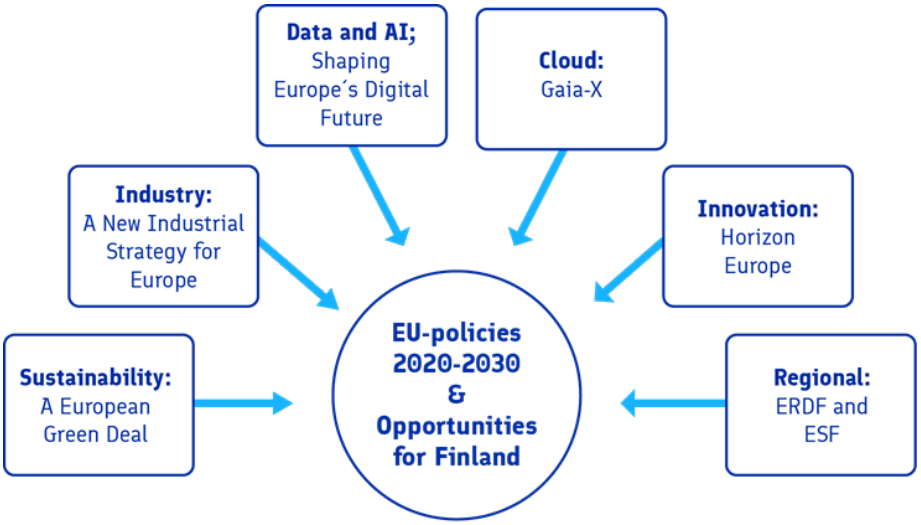


Figure 6. ***Key European initiatives providing Industry X opportunity spaces for Finland***

In terms of logistics, the rail connection from Tornio-Haaparanta area towards Kouvola will have significant importance in the future, as it connects the business areas of Arctic Sea in Norway and Sweden to the Kouvola logistics hub. This is anticipated to become an important rail logistics hub towards Asia.

2.3 Finnish ICT and Manufacturing Ecosystems

The forming of business and innovation ecosystems in Finland has been active in the past decade, resulting from EU-level strategies related to innovation hubs and smart specialization. Ecosystems form a concentrated pool of smart specialization, high technology assets and the latest knowledge for companies to cooperate and develop together with their coopetitors.

WE HAVE TENS OF ECOSYSTEMS, BUT LITTLE COLLABORATION BETWEEN THEM, AND CHALLENGES IN THE MODE CHANGE FROM PUBLIC TO MARKET-DRIVEN FUNDING

Most well-known ecosystems in the manufacturing and ICT-sectors are focused on digitalization and intelligent industry (DIMECC), digital fabrication and printed intelligence (Fab Labs & PrintoCent), digitalization of manufacturing industry and engineering (Reboot IoT Factory and MEX), robotics (RoboCoast), AI solutions for various domains and IoT (Analytics+, SuperIoT), and next generation tele-communications (5G Test Network and 6G Flagship). This is by no means an exhaus-tive list.

Allied ICT Finland is the one-stop shop connecting these emerging technological and industrial ecosystems. AIF ecosystems seek to provide a unified interface to market leads, partnership, top knowledge, and sales. The aim for all these ecosystems is to become internationally recognized and economically self-sustainable.

Currently, there are a number of challenges that these ecosystems face in order to reach a more sustained and market-oriented operating model:

- **Collaboration between ecosystems**: Ecosystems should be more aware of each other and each other's offering.
- **Proving value to company partners**: Ecosystems face a challenge in becoming valuable enough for company partners, so that financial basis could be organized within the partner network. Virtually all ecosystems in Finland start through some form of public funding, facilitated by research organizations. This creates a mindset for company partners, where the ecosystem is something that can be joined for free and may bring some business benefits in the future. Against this mindset, it is difficult to justify membership fees or other forms of self-sustaining.
- **Achieving international visibility**: Many of the ecosystems are within the EU process of establishing European Digital Innovation Hubs (EDIHs). The EDIH status gives one channel of visibility within the EU. In addition, ecosystems need agile processes for bringing customers from the introduction phase to negotiations on co-operation.

3. INDUSTRY FUTURE AND HOW TO GO THERE

Our analysis concludes that continuing as such is not an option for Finland to survive. Our industry is in the crossroads and a road to go on must be chosen. Our view is that due to the development of technologies and customer needs, the industry paradigms will evolve from the current Industry 4.0 towards Industry 6.0 in the next 10 to 15 years. In that development, the merging paths of digitalization and sustainability will be significant. This shapes the road forward to obtain the deeply needed sustainability and antifragility goals.

3.1 Future Path Towards Industry 6.0

Table 1 summarizes the anticipated path towards Industry 6.0. To our knowledge, this is the first time this path has been analysed by any country to the depths presented here.

Table 1. ***The anticipated path towards Industry 6.0***

INDUSTRY PARADIGM	GOALS	CURRENT STATE IN FINLAND
INDUSTRY 4.0: CONNECT – IOT TO CREATE CYBER-PHYSICAL SYSTEMS FOR ANALYTICS-BASED ACTIONABLE INSIGHTS	• Analytics-based actionable insights • Improved flexibility • Higher efficiency • Higher quality • Lower cycle times • Faster speed-to-market	• Finnish companies are pretty well in I4.0 level, especially larger companies. For SMEs the situation varies largely. • Data collection from legacy systems is a main bottleneck • RDI-level is not sufficient and collaboration between ICT and industry domain research is far from being at a sufficient level. • Software and connectivity are main examples of the areas where Finnish companies are not utilizing the state-of-the art opportunities • Robustness of the system is proven weak (by COVID-19) • Software reliance on USA • Component reliance on China • Sustainability research is not at a sufficient level • Finland is not sufficiently linked with international research initiatives
INDUSTRY 5.0: CO-EXIST – HUMAN-MACHINE CO-CREATIVE	• Co-creative resilient and sustainable cyber-physical systems for mass-customization (From Industry 4.0 flexibility and Industry 5.0 agility)	• Finnish research is already creating bits and pieces for that direction, but not

RESILIENT AND SUSTAINABLE CYBER-PHYSICAL SYSTEMS FOR MASS-CUSTOMIZATION	• Humans in focus • Environmental sustainability in focus • Re/de-manufacturing • zero waste, zero emission • Circular economy • Software-enabled, intelligent products • Software-extended, intelligence-enabled products • New or better offerings based on product usage insights • Improved experience and increased value to the customer	covering all necessary ingredients • Strengths especially in 5G and AI
INDUSTRY 6.0: UBIQUITOUS – CUSTOMER DRIVEN VIRTUALIZED ANTIFRAGILE MANUFACTURING	• Customer driven virtualized antifragile manufacturing • Hyperconnected factories in complex, dynamic supply chains and value networks, where data flows across different administration domains • Autonomous adaptability and reconfiguration • For example, take a picture of a rough sketch and click “make it” • Role of human dramatically changes in manufacturing • Quantum computing boosting the quality and performance of existing AI models, and opening opportunities for completely new models. • Production is like cloud capacity, “factories” sell it like, e.g., Amazon computing capacity • Lot-size-1 made economically feasible • Sustainability focus extends from environmental to full-fledged sustainability • Transparency in all levels makes this visible • Co-innovation with customers becomes prevalent • End-to-end solutions blur industry boundaries	• Finland can take the global leadership in defining I6.0 with systematic work and collaborative efforts

3.2 Proposals for the Finnish Vision and Agenda

Continuing as such is not an option. Instead, we need a strong and motivating joint vision and agenda to implement it. This white paper proposes one.

VISION STATEMENT:
INDUSTRY 6.0 IS DEFINED IN FINLAND BY PROACTIVE GAME-CHANGING ACTIONS

The challenges created by the survival game are extremely difficult. We believe that this vision provides opportunities to solve them. However, they will not be solved in one to three years. Thus, long-term commitment is required for the imple-mentation of the agenda.

THE SURVIVAL GAME IS LIKE A MARATHON, AGENDA MUST BE IMPLEMENTED THROUGH LONG-TERM INVESTMENTS

More importantly, this demanding vision is impossible to be implemented just by our own resources and knowledge. The whole of Europe is facing similar challenges and likewise engaged with the reshoring of Industry. Finland should seek deep collaborations with European partners, especially manufacturing powerhouses such as Germany and Northern Italy. Implementation of the new Multiannual Financial Framework (MFF), including COVID-19 recovery fund, is under way in Europe. The precise implementation agendas will have a significant amount of funding for the topics supporting this vision. We suggest that dedicated networking and influencing actions are needed, at this moment, and for this purpose. Through joint European collaborations much more can be achieved than otherwise possible and much more than achieved today.

FINLAND CAN BE AN INFLUENTIAL EUROPEAN RDI-POWERHOUSE THROUGH PARTNERING

SCIENCE AND TECHNOLOGY MINISTER LEADING A HOLISTIC AGENDA

The survival game after all the shocks is so harsh that we propose the nomination of a Science and Technology minister to steer the activities. Their task would be to steer the implementation of the agenda holistically from research and development to deployment in the renewal of industrial production. Without a holistic approach, this survival game cannot be won.

SOLVING SUBPROBLEMS IS NOT AN OPTION – THE WEAKEST LINK DEFINES THE STRENGTH OF THE SYSTEM. THE AGENDA MUST BE HOLISTIC.

SHARPENING SMART-SPECIALIZATION STRATEGIES

Current smart-specialization strategies are too vague and do not lead into desired effects. Better crafted strategies will lead to a more targeted allocation of resources dedicated to the right local strengths and needs. It will also make it easier to utilize funding from the European Regional Development Fund (ERDF) more efficiently and in a coordinated matter. Collaboration maximising individual regional capabilities is a key to optimizing the joint Finnish path towards Industry 6.0.

SPECIALIZE AND COLLABORATE

VIRTUAL INDUSTRY 6.0 UNIVERSITY

A significant portion of the value in the future of industry comes from ICT-based solutions. Therefore, significant research efforts should be placed on ICT in industrial domains. Currently, the top ICT research results have not been widely utilized by Finnish industry. The main reasons have been the isolation of ICT research from industry -relevant technology areas. The isolation takes place on researcher levels, but especially also on the university-company level. Hence, many companies, especially SMEs, are using off-the-shelf solutions that are far from optimal. Crucial standardization has not yet started properly. All this requires cross-pollination and activation of ICT professors to be more active towards this sector. Isolation of resources also affect education and international impacts. By combining efforts in a well-coordinated manner, significant cost-savings can be obtained in education. This also offers a way to increase the quality of education.

WE PROPOSE:

Creation of the Virtual Industry 6.0 University (Figure 7). App-roximately 10 new Industrial ICT professors and additional postdocs are needed to fill the gaps. These professors and existing ones need to be actively networked inside this virtual structure and towards Europe. Networking covers all aspects: education, research, internationalization, and industry collaboration.

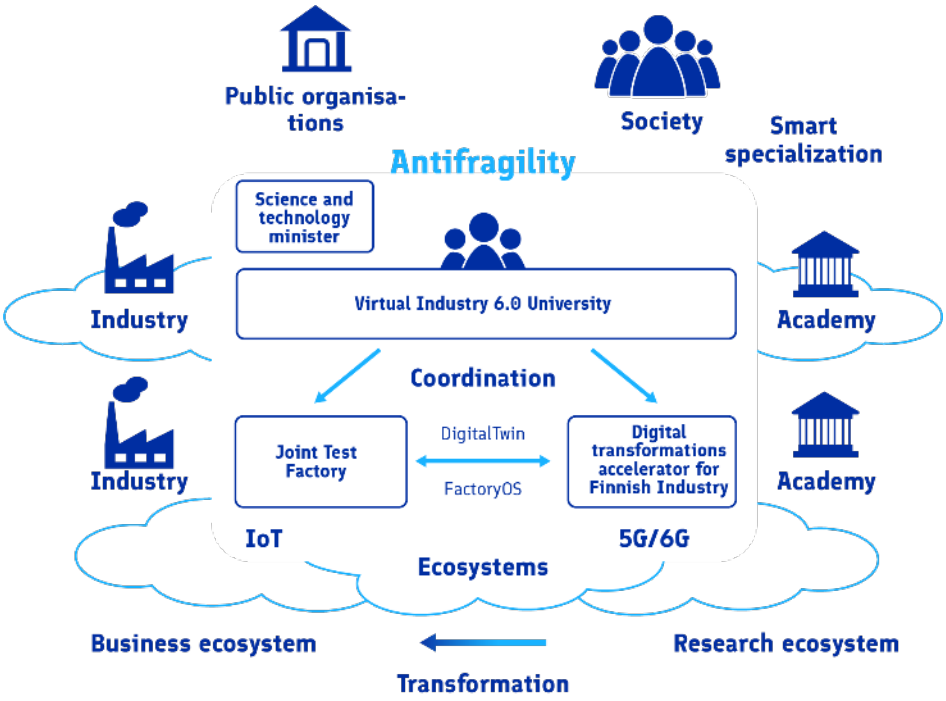


Figure 7. ***Virtual Industry 6.0 University***

NEEDED FUNDING:

- Ministry of Education and Culture: Professors' and postdocs' salaries and other costs

- R&D&I programs:

  - Academy of Finland: Emerging Industrial Technologies (2021-2030)
  - Academy of Finland: Antifragile society (2021-2030)
  - Business Finland: Industrial software (2021-2025)
  - Business Finland: AI for industry (2021-2030)
  - Business Finland: Ecosystem Antifragility (2021-2025)
  - Business Finland: Ecosystem cross-pollination funding (2021-2030)

- Business Finland or The Finnish Innovation Fund Sitra: Large scale industry-driven PPP-programs (with a renewed PPP-model utilizing experience from ex-SHOKs, AIF, BF-ecosystems, etc.) for the fundamental R&D&I topics, 3 types [21]
  - 'Much faster horses'. Solving important problems by creating totally new methods and technologies
    - co-create, research push

[21] See: Kestävänä kasvun työryhmä (2021) Kestävä talouskasvu ja hyvinvointimme tulevaisuus. Työ- ja elinkeinoministeriön julkaisuja 2021:12. Työ- ja elinkeinoministeriö. http://urn.fi/URN:ISBN:978-952-327-599-7

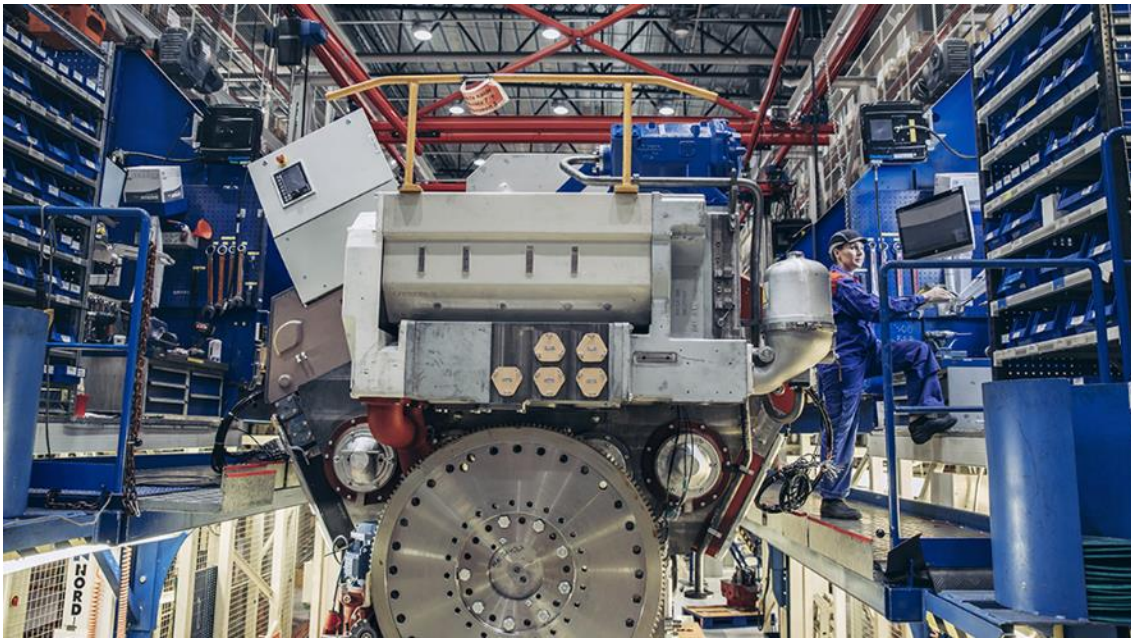
  - Applying totally new technologies to already industrialized methods
    - co-innovate, research pull, voice of customer from industry
  - Getting the most out of the already industrialized, existing methods and technologies
    - co-implementation, research support

- Business Finland: Exchange program for ICT researchers visiting Industry 6.0 companies

- The Ministry of Economic Affairs and Employment: EU influencing back-office (targeting to multiply the funding to the theme by four)
  - Create and sustain a strong strategy of aligning Finnish initiatives with European initiatives and maximising EU funding for research, development, innovation and technology deployment in Finland
  - Preparing a new vision paper on the integration of Industry 6.0 initiatives in Next Generation EU (NGEU) and the Digital Europe Programme (DIGITAL).
  - Developing a Placing Finland at the centre of Gaia-X and Destination Earth (DestinE)-initiatives
  - Making Finland a leader in the EU single market systems for standardization and certification

- Ministry of Education and Culture: ICT for Industry BSc., MSc and reskilling package creation
  - Massive Open Online Courses (MOOCs) in both Finnish and English targeting special sectors and skills
  - Promotion of continuous education and life-long learning and adaptation

- Ministry of Education and Culture: Education of 1000 more software professionals annually with understanding of industry needs



JOINT TEST FACTORY

The majority of future industrial solutions are created in networks of companies, researchers and operators that need to utilize cutting-edge RDI environments, take advantage of smart specialization with well-defined accesses to technology, tools and documentation. Currently, there is little or no funding available to systematically ensure that our RDI investments are made available for the other potential users outside the host-organization, with very few (e.g. 6G Flagship, CSC LUMO) exceptions. Environments are mostly offered in silos; they are typically hard to find or understand and use efficiently in industrial co-innovation. Allied ICT Finland is hosting an inventory of shared RDI environments aiming to improve the discovery, adoption and mixing of different technologies through shared platforms and test environments, everything from AI to Wireless, but this is not sufficient for the survival game. How to utilize our RDI environments is an industry competitiveness issue to the greatest extent.

We believe that shared RDI environments have potential to combine the best features of platform economy with smart specialization. These environments can become important vehicles for future growth, resilience and sustainability by integrating networks to networks. They are especially valuable in smart co-creation by offering creativity and productivity boost to 1) evaluate and adopt best technologies, tools and practices, 2) to offer low-barrier entry to R&D productization environments, and 3) to build a continuous stream of solutions. Next industry generations will require much better cross-pollination (ecosystem of ecosystems) and interplay of technologies to untap full power of smart specialization. It can only be reached with no-frills access to multitude of latest platforms, technology environments and co-creation tools.

Companies are having state-of-the-art RDI environments that cannot be reached by other companies and research organizations. An example of utilizing factories as innovation platforms for joint SME-research experimentation is the Reboot IoT Factory model. The Reboot operative model is based on agile co-creation and experience sharing within real-world production environments. Each participating factory commits as a research and development platform for proof-of-concept experiments, which combine technology research and factory digitalization needs. Joint factory-research concepting creates opportunities and demand for commercial adoption of new technologies, pulling in the SME network through focused subcontracting.

WE PROPOSE:

Creation of a joint test factory opening access of the environments broadly and serving as a testbed for Finnish winning platforms. With that, we can create a new pilot model in Finland combining the models of smart specialization, smart co-creation and shared RDI environments to ensure our industry competitiveness.

NEEDED FUNDING:

- The Ministry of Economic Affairs and Employment: Test factory task force (2021-2022) specifying the "factory" consisting of the existing set of RDI environments and identified missing ones. Environments will be connected with each other in order to be able to test more and more complicated cases.
- Business Finland: SRE as a service – a well-documented and low-barrier access to existing (including company) RDI environments, complemented with "CSC-like" service to help companies and researchers to discover and use new technologies in all new projects (2021-2030)
- Business Finland: Data as a service – an access for real-time real industrial data from industry to research (2021-2030)
- The Finnish Climate Fund: Missing infra creation (2021-2030)
- Academy of Finland: Finnish Research Infrastructure (FIRI) funding for industrial RDI environments (ongoing activity)
- The Finnish Innovation Fund Sitra or The Finnish Climate Fund: Dedicated programs for the creation of platforms to be globally scaled, candidates include: (2021-2030)
    - Intelligent AI-powered, 5G/6G enabled Edge
        - Utilizing research from the flagships 6G, Finnish Center for Artificial Intelligence FCAI and Photonics Research and Innovation (PREIN), and the Finnish System-on-Chip know-how
    - Industry Operating System (FactoryOS)
    - Human-centered factory digital twin (connecting humans with machines and robots or cobots)
    - Factory Appstore, especially for AI-models
- Ministry of Education and Culture: Edufactory and development of ICT toolboxes for education (ongoing activity)

DIGITAL TRANSFORMATIONS ACCELERATOR FOR FINNISH INDUSTRY

The key to unlocking future Finnish industrial success is not the existence of siloed knowledge, but an efficient uptake of transformative technologies within Finnish manufacturing and industrial companies. Therefore, results need to be efficiently delivered to be used widely in the industry. A specific accelerator is needed for that purpose. The responsibilities of the accelerator will change with emerging technologies, but starting responsibilities are likely to include:

- 5G/6G utilization programs
- Utilizing AI in manufacturing programs
- SME digital transformation program
- CDO support forum
- Sustainable Industry X-business modeling program
- Experimental sustainable and digital manufacturing renewal program

Implementation of digital transformations accelerators should be aligned with the designation of European Digital Innovation Hubs will be launched in Finland. Finland's candidates are:

- FAIR – Finnish AI Region (responsible organisation VTT Technical Research of Finland Ltd)
- SIX Manufacturing EDIH (Tamlink Ltd)
- Location Innovation Hub (LIH) (National Land Survey of Finland/Finnish Geospatial Research Institute (NLS FGI)
- 5STAR eCorridors (DIMECC Ltd)
- WellLake EDIH (Business Jyväskylä)
- HealthHub Finland (Turku Science Park Ltd)
- Robocoast EDIH Consortium (Prizztech Ltd)
- Arctic-EDIH (University of Oulu)

A Digital Innovation Hub can provide many of the services, possibly. We propose designing this accelerator at the same time with the election of the European Digital Innovation Hubs.

4. CONCLUSION

This white paper has been conceived in a time of global crisis – the COVID-19 pandemic. The pandemic has joined several other existing pressure points necessitating Finnish industrial transformation. Backlashes to globalisation, emerging tech behemoths, barriers for trade with Russia, climate change, and the biodiversity crisis all foster a drive for radical adaptation towards flexible, sustainable, intelligent, and antifragile manufacturing in Finland. We define this as "Industry 6.0: Ubiquitous customer-driven virtualized antifragile manufacturing".

Finland has a unique chance to be a first-mover and a game-changer within this field, consolidating both existing Finnish industry and developing new technological business opportunities emerging out of Finnish firms and ecosystems. It requires strong initiatives, dedicated funding, and new modes of collaboration between hitherto siloed industrial ecosystems. We need to raise the level of ICT-knowledge across industry; we need multidisciplinary research, development, and innovation, and we need a strategy for long-term public commitment. The development of active networks and collaboration is essential. Currently, the Artificial Intelligence 4.0 programme is an important initiative for the development towards Industry 6.0, and proceeding with AI 4.0 promotes Industry 6.0, too.

WE PROPOSE THAT FINLAND:

1. Develops and adopts a holistic vision for Industry 6.0 with the support of all major stakeholders.

2. Nominates a Science and Technology minister to steer the Industry 6.0-activities and their implementation.

3. Executes a coordinated refinement of existing regional smart-specialization strategies to enhance existing regional strengths and utilize funding from the European Regional Development Fund (ERDF) more efficiently.

4. Creates the Virtual Industry 6.0 University with approximately 10 new Industrial ICT professors and additional postdocs needed to fill the gaps, and active networks.

5. Creates a joint test factory opening access of the environments broadly and serving as a testbed for Finnish winning platforms and creating a new pilot model in Finland combining the models of smart specialization, smart co-creation and shared RDI environments to ensure our industry competitiveness.

6. Establishes a digital transformation accelerator for Finnish industry aligning the accelerator to European Digital Innovation Hubs selections.

This white paper shows how Finland can lead the global path towards Industry 6.0. We hope it helps inspire industrial stakeholders to lead future actions in their own agencies and organizations, and policymakers to initiate the development by taking the first steps towards antifragile manufacturing for people, planet, and profit with passion.

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